All photos: Charles Ross & Son Co.

Feature Report

The Unexpected Rewards of Testing a Mixer

For custom mixers and blenders, verification is only one benefit. Testing can open the door to further improvement

FIGURE 1. A two-wing anchor agitator is a cost-efficient answer to limited flow within a mix vessel. For batches up to approximately 200,000 cP, the anchor can generate significant flow, accelerate the dispersion and hasten progress toward batch uniformity

Ken Langhorn
Charles Ross & Son Co.

Among all the engineers who will be involved in the purchase of a mixer or blender next year, roughly half will welcome a change in their production method. The other half will be determined to prevent it.

Searching for the right equipment to make a new product or boost current production, about 50% of users will conduct open-eyed tests in the laboratory of a mixing equipment manufacturer.[1] They will test a variety of mixers and ancillary equipment. While manipulating parameters such as shear, viscosity and flow rates, they will experiment with various types and combinations of agitators. They will explore the effects of applying vacuum or altering batch temperature at certain stages of the mix cycle.

Another 25% of users will conduct tests, but their mission will be due diligence, not exploration. Their goal will be to control risk by collecting data and confirming an equipment selection prior to committing to a purchase or rental. In other words, they want to avoid making an expensive mistake.

The remaining 25% will not test at all. Relying on long experience with familiar equipment and a well-understood application, they will replace worn-out equipment (or perhaps scale up) with the same equipment as before, intending only to replicate their existing process.

Who tests, and who should

The decision to test often reflects the personal attitude of a key manager or the collective values of a management team. Some welcome the challenge and potential rewards associated with change, while others prefer the security of continuing to operate "the way we've always done it."

Corporate culture and the company's competitive situation can also influence the desire to test. Some companies promote an aggressive, unrelenting search for every possible competitive advantage. Others — especially those businesses that haven't yet been pressured by global competition — are more complacent.

In fact, every manufacturing company must balance the opposing goals of innovation versus consistency, creativity versus predictability, change versus no-change. In most companies, change is welcome during product development but unwelcome afterward. After all, we all know that innovation is the engine of product development. It requires an open-minded approach to equipment selection, and this often includes equipment testing.

But on the plant floor, consistency is paramount. The traditional approach to production is to apply highly consistent techniques to manufacture a consistent product, while cutting costs and scaling production to meet demand. This usually includes standardizing the equipment used on the plant floor. As demand grows, scaleup generally means adding larger models of equipment already in use. When a piece of equipment wears out, it is replaced with a newer version of the same unit, based on the expectation that it will perform exactly as its predecessor did.

This reverence for consistency and stability in production has been the norm for many years. But intensifying competition in our global economy may call for a change of heart, especially where mixing equipment is concerned.

The trouble with disciplined consistency in production is that mixing technology is constantly evolving. In some equipment categories, such as high-shear rotor/stator mixing, high-speed powder injection and high-viscosity planetary mixing, the change during just the last few years has been profound.

As mixing technology has advanced, the capabilities of even the oldest and most familiar types of mixers have expanded — along with our understanding of how they can be used and what they can accomplish. Applications that were once considered appropriate for only one type of mixer can now be accomplished with a variety of equipment strategies, each offering a unique combination of advantages and disadvantages.

1. The mixers and blenders we consider in this discussion belong to the broad category of "custom" mixers and blenders – not standard, off-the-shelf turbine and propeller mixers that are regularly purchased without any need for testing.

FIGURE 2. This double planetary/disperser hybrid mixer is equipped with a pair of high speed dispersers on each of two shafts, in addition to two sets of helical planetary blades. The addition of disperser blades to the traditional double planetary mixer enables it to handle applications that include both high-viscosity and low-viscosity stages

Recognizing this, many forward-thinking production engineers are now testing periodically, and not just when a plant expansion or the addition of a new production line provides an obvious opportunity to upgrade. They test to stay current on new developments in mixing technology, explore opportunities to improve both current and future production lines, and to make sure their companies remain in the passing lane of global competition.

Go with the flow

Many engineers who visit the test laboratory of a mixer manufacturer are surprised by the fact that subtle changes in a mixer's configuration or operation can yield an enormous improvement in performance. Virtually all arrive with at least an idea of the type of mixer they want to use, and often their instincts turn out to be correct — with the simple addition of another agitator.

Example 1: Adding a low-shear agitator to create a uniform pigment dispersion.[2] The production engineer in this case had used a high speed disperser for years to disperse a variety of liquid pigment blends in a base material. Operating in a batch with a lotion-like consistency — a viscosity of approximately 20,000 cP — the disperser provided plenty of shear energy. A 10 h.p. disperser in a 50-gal batch required about 60 min to complete the dispersion. Trials were arranged to search for potential improvements related to blade size and design, and perhaps the use of multiple blades mounted on a single shaft.

At this batch size and viscosity, an 8-in.-dia. high-speed disperser operating with a tip speed of 5,000 ft/min creates only a mild vortex. Pigments added to the light-colored base material provide a vivid display of uniformity — or in this case, slow progress toward uniformity. Material near the disperser was quickly dispersed and assumed a uniform appearance. Meanwhile, slow-moving swirls of color near the vessel wall indicated limited flow within the batch.

In actual production, the cycle time for this application had been 60 minutes, but most of that time was wasted. The mixer dispersed the pigments immediately once they contacted the blade. The limiting factor was the flow within the vessel, not the blade design. We recognized that flow could be improved by adding a low-shear agitator that would complement the action of the high shear agitator.

In a dual-shaft mixer, a slow-turning, two-wing anchor agitator improves flow by moving material from the vessel wall toward the high shear agitator (Figure 1). Teflon scrapers prevent a layer from remaining on the wall and bottom of the vessel. By improving flow, the anchor essentially feeds material to the disperser and accelerates the dispersion process.

With the complementary action of these two agitators, the batch reached target uniformity in 15 min, a 75% improvement compared to the cycle time required by the disperser operating alone.

An agitator for each stage

Mix cycles can often be accelerated by identifying key inflection points during the process and recognizing the need to apply different forms of agitation during different stages. Substantial changes in viscosity, for example, generally distinguish one mixing stage from another and signal the need for a change in agitation.

Example 2: Adding a high shear agitator to accommodate the lowered viscosity of a conductive coating. The double planetary mixer has been around for more than 50 years, and it is still a reliable workhorse for high-viscosity mixing. Since the dispersion of conductive carbon is generally processed at viscosities up to about 1 million cP during the mix cycle, it is a typical application for the double planetary mixer. In this scenario, a manufacturer had already used double planetary mixers to prepare conductive coatings. He scheduled a test to confirm the choice of a new mixer for scale-up.

Replicating the process in the test laboratory, conductive carbon powders were added to a solvent base, along with a variety of binder materials. Planetary mixing required 20 min of kneading at 1 million cP.

The next phase of the process was far more time-consuming. Letting the batch down from 1 million cP to 10,000 cP required 90 min, because the solvent must be added slowly. Dosing the solvent gradually allows it to be incorporated without forming clumps of the conductive paste, which bob in the low-viscosity mix and resist breaking down further.

The slow pace of the let-down stage of this cycle made it an excellent target for improvement. The key was to understand that it was slow only because the mixing action of the planetary blades became steadily less effective as viscosity fell. At viscosities below 200,000 cP, planetary blades generate very little shear and are unable to incorporate the low-viscosity diluent into the paste.

The solution was to switch from a traditional double planetary to a double planetary/disperser hybrid mixer (Figure 2). This mixer extends the versatility of the double planetary mixer by adding two disperser shafts, each of which can be equipped with one or two disperser blades. These high-speed agitators orbit the vessel in tandem with the planetary blades and apply intense shear.

In this application, the high-shear agitators were turned on for the

2. All of the test scenarios in this article are drawn from actual trials in the Ross Test & Development Center in Hauppauge, NY. However, certain details were omitted or changed to safeguard customer confidentiality or clarify the essential message of the example.

let-down, when the batch viscosity reached 200,000 cP, and they became steadily more efficient as the batch viscosity dropped further. The dispersers easily disintegrated all clumps of paste, and the 90-min let-down stage was shortened to 15 min.

FIGURES 3 and 4. Sigma blade mixers (above) apply great power to mix materials at extremely high levels of viscosity. Recently, however, innovative helical blades (right) have extended the working viscosity of double planetary mixers significantly. This has made many high-viscosity applications appropriate for either a sigma blade mixer or a planetary mixer

Sometimes more is less

Successful laboratory tests are generally characterized by such measures as a faster mix cycle, a finer emulsion or dispersion, improved end-product quality, or increased efficiency (the result of combining multiple process steps in a single machine, for example). But sometimes a test can be called a success after producing no visible signs of product or process improvement — and even after requiring more pieces of equipment to achieve the same effect as before.

Example 3: Mixing high-viscosity polymers with less costly equipment. With high tensile strength and elasticity, flexible polymer blends are used in many industries to make a multitude of extruded products. They are commonly mixed in a sigma blade mixer, which applies enormous pressure to crush the polymer pellets while generating enough friction and heat to melt the polymers in a 15-gal batch in about 20 min. The mixing that follows requires another 20 min.

The sigma blade mixer (Figure 3) is immensely powerful, and with the batch viscosity at about 5 million cP, this application is hardly challenging. But it is also a particularly expensive mixer, so it is the best choice only when the viscosity exceeds the capabilities of all other mixers. In fact, the customer in this case had been using sigma blade mixers because he believed there was no alternative.

Our test strategy was to apply recent design advances in planetary blade design that have extended the working capacity of double planetary mixers well above their previous working limit of about 2 million cP. Equipped with helical blades (Figure 4), a double planetary mixer can handle viscosities up to 8 million cP, which makes it an attractive alternative to the sigma blade mixer in many applications.

Compared to traditional, rectangular planetary blades, the new generation of blades is helical and precisely sloped. The graceful slope enables the helical blades to pass one another with a slicing motion in the vessel. This prevents the sudden spike in power that typically occurs when the vertical arms of rectangular blades pass one another in a high-viscosity batch.

By suppressing this power spike, the working viscosity of a double planetary mixer equipped with helical blades extends well beyond the 5 million cP level this application requires. But in this case the planetary mixer required additional equipment to melt the polymers before mixing could begin.

This test was conducted in a 40-gal double planetary mixer with thermal jacketing, through which we circulated oil at 350°F. The polymers required 20 min to melt and another 20 min to mix. They were then discharged with a hydraulically actuated, automatic discharge system.

The test results included no change in cycle time or product quality, and the test required three pieces of equipment where one had been used before. But it was clearly successful because the total cost of the new system was more than 50% lower than the cost of a new sigma blade mixer.

Advantages of pre-milling

Preconceptions built over many years of practice are often hard to dispel. In a test environment, they can be especially costly if they are allowed to discourage exploration. Engineers who are willing to consider unfamiliar technologies and unexpected solutions are often rewarded with quantum improvements in production.

Example 4: An ultra-high shear pre-mill makes downstream media milling unnecessary for an aerospace pigment dispersion. Media mills are a common sight in plants producing fine dispersions. They can produce excellent results, but they are also notorious for their slow throughput and the laborious cleaning and maintenance they require. To address these shortcomings, high-speed rotor/stator mixers are commonly used to pre-mill materials, reduce particle size significantly, and shorten the cycle time required by the mill.

This test was arranged to measure the performance of a traditional, single-stage high-shear mixer serving as a pre-milling device (Figure 5). To produce an aerospace coating, the engineer had been pre-mixing pigments and an epoxy-based material in a disperser-agitated vessel, then sending the mix downstream to the mill. His goal was to save time and increase production by feeding pre-milled material to the media mill.

The first test using the single-stage rotor/stator mixer was successful. A single pass through the inline mixer, operating with a rotor/stator developing tip speeds of 3,500 ft/min, easily met the target particle size.

A second test explored the performance of a completely different rotor/stator concept, and the results were even more dramatic. This time, the pre-mix was fed through an ultra-high-shear inline mixer (Figure 6).

Unlike the traditional single-stage high shear mixer, the rotor/stator generator in the alternative setup does not include conventional blades. Instead, the rotor and stator are comprised of

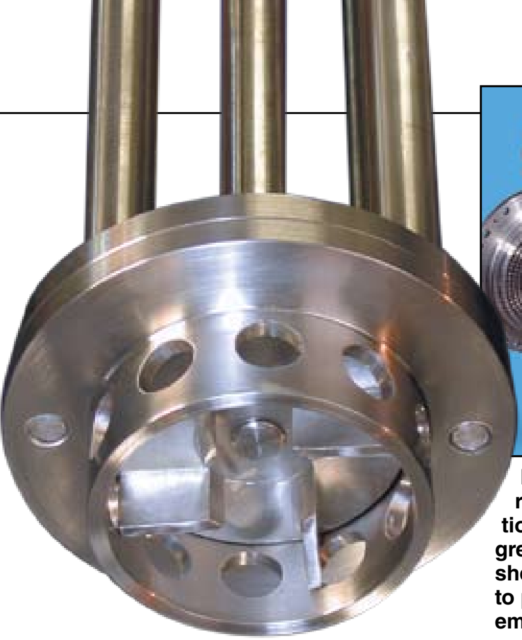


FIGURE 6. **This rotor/stator generator represents a sharp departure from traditional rotor/stator design. This innovation greatly extended the application of high shear rotor/stator mixers by enabling them to produce much finer dispersions and emulsions**

FIGURE 7. **This batch-configured high shear mixer is equipped with a wand and feed tube that terminates beneath the surface of the batch. Powders are sucked through the tube and injected directly into the high shear zone, where they are dispersed instantly**

FIGURE 5. **In the single-stage high shear mixer, a high speed rotor turns within a fixed stator, applies intense shear in the high shear zone and expels material radially through holes or slots in the stator. Available in either batch or inline configurations, this mixer has been used for many years to pre-mill dispersions prior to media milling**

many concentric rows of intermeshing teeth. The mix material begins at the center of the generator and moves outward through the rotor/stator teeth. With extremely close tolerances and high tip speeds (up to 18,000 ft/min), the shear applied to the material in each pass is extraordinarily intense.

In this test, the ultra-high-shear rotor/stator mixer produced a "pre-milled" product that met the specification for final production in the media mill. The low-flow, high-maintenance mill was replaced by a high-flow, high-speed inline mixer. Overall production was increased and long-term operating costs were cut significantly.

A fast remedy for fish eyes

A simple switch to a more aggressive mixer design — from a low shear propeller or turbine to a high shear rotor/stator mixer, for example — can yield startling results. But in many cases, to optimize the mixing process, a high shear generator must be accompanied by an auxiliary device that delivers raw material directly to the high shear zone.

Example 5: Dispersing powders with sub-surface injection turns an overnight chore into a 5-min. process. Gum thickeners are used by process engineers worldwide to make a multitude of products from doughnut fillings to the electrodes in flashlight batteries. They are extraordinarily versatile, but they are also frustrating to work with, because they are extremely hard to hydrate uniformly.

Instead of dispersing easily, most gum thickeners float on the surface of a liquid batch. Even when a high-shear mixer is used to generate a vigorous vortex, the powder will float persistently, occasionally forming bulging "fish eyes," turning slow circles around the rim of the vortex as it stubbornly sinks into the liquid.

The engineer in this case followed the century-old custom of adding gum thickener to a water-based mix, in a vessel equipped with a propeller, and letting it run overnight. By morning, the gum had finally dispersed and the mix was ready for the next step. A test was arranged to assess the value of replacing the propeller with a batch rotor/stator mixer.

In a 100-gal vessel, a 10-h.p. high-shear mixer created a high quality dispersion and reduced the mix cycle from 8 h to 1 h (Figure 7). To anyone who has seen a rotor/stator mixer in action, this was actually not surprising.

A second test included a similar rotor/stator mixer, but this one was equipped with a sub-surface powder injection device. The device sucked the free-flowing powders through a tube that delivered them — still dry — directly to the sub-surface high-shear zone of the mixer, where they were dispersed immediately. For a 2% concentration of gum thickener, the system injected all 16.7 lb of powder and completed the dispersion in 5 min.

Maximize the value of testing

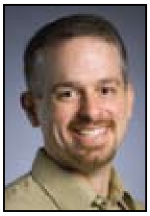
Process engineers who do not step away from their process lines periodically to reassess their mixing equipment strategies are assuming significant risk, especially in highly competitive markets. As mixing technology continues to evolve, each advance you overlook may wind up on the plant floor of your competitors. And, as we have seen, even seemingly small changes in your equipment configuration or mixing technique can yield a significant improvement in production — and an important competitive advantage.

The best course is to visit the laboratory of a mixer manufacturer and test using your own ingredients. Replicate your process environment as closely as possible. Choose a laboratory that provides onsite analytical evaluation of your test results, so you can modify your testing in realtime, based on quantitative results.

Most important, be sure to test a variety of equipment, not just the equipment you expect to purchase or rent. In order to discover unexpected success, you'll have to explore some unfamiliar territory. ■

Edited by Rebekkah Marshall

Author



Ken Langhorn is technical director at Charles Ross & Son Co. (710 Old Willets Path, Hauppauge, NY 11788, Phone: 631-234-0500; Fax: 631-234-0691; Email: klanghorn@mixers.com). He has published many articles on mixing and blending technology. Formerly an R&D specialist at Ross, he holds multiple patents for innovations in high shear and high viscosity mixing. As manager of the Ross Test & Development Center, he oversees a large program of testing and process optimization for customers, along with operations in the company's adjacent analytical laboratory.